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DRAFT TECHNICAL MEMORANDUM NO. 5
MASS LOADING RESULTS
CALIFORNIA URBAN WATER AGENCIES
STUDY OF DRINKING WATER QUALITY IN DELTA TRIBUTARIES

September 19, 1994

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EXECUTIVE SUMMARY

Concentrations and loads of key drinking water contaminants were evaluated for the major discharges to the Delta tributary watershed (the Sacramento and San Joaquin basins) and at benchmark receiving water locations. The objective was to determine whether alternative management of those major discharges could be expected to improve the water quality of the Delta as a source of drinking water. At the first Project Advisory Committee (PAC) meeting on July 14, 1993, the PAC and project team developed a list of discharges, benchmark locations, and drinking water contaminants to be evaluated. As the study proceeded, the project team found that there were insufficient data on many of the contaminants of concern at the benchmark locations and for the discharges. At the July 1994 PAC meeting, the PAC directed the project team to evaluate the following discharges, benchmark locations, and contaminants:

1. The major discharges evaluated in the Sacramento Basin were Sacramento Slough and Colusa Basin Drain agricultural drainage, Sacramento urban runoff, Sacramento combined sewer overflow, and the Sacramento Regional Wastewater Treatment Plant (SRWTP) effluent discharge. The major discharges evaluated in the San Joaquin Basin were Mud and Salt slough agricultural drainage.

2. The benchmark locations evaluated were the Sacramento River at Greene's Landing, the San Joaquin River at Vernalis and the Banks Pumping Plant in the Delta.

3. The contaminants evaluated were organic carbon, alkalinity, bromide, arsenic, total dissolved solids, and nutrients (ammonia. nitrate, phosphorus).

Based on data from 1990-1993, the key findings are:

Organic carbon. The concentrations of organic carbon will not likely be reduced at any of the benchmark locations by control of the discharges examined. If additional monitoring of Sacramento urban runoff confirms it as a significant source of organic carbon, control measures may be identified that would reduce the organic carbon concentrations at Greene's Landing.

Alkalinity. Alkalinity loads were not calculated. Based on the concentrations, the discharges would not likely have a significant effect on downstream alkalinity.

Bromide. The source of bromide is seawater that intrudes into the Delta, and the recirculation of bromide via the San Joaquin River. Control of the discharges identified in this study would not likely reduce bromide concentrations at the benchmark locations.

Arsenic. Arsenic concentrations at the benchmark locations will not be reduced by controlling any of the discharges examined. Additional monitoring of the Yuba and Bear Rivers watershed may indicate that controlling mine drainage would improve water quality at Greene's Landing. It is uncertain, however, whether controlling mine drainage in the upper watershed would significantly affect arsenic concentrations downstream at Greene's Landing.

Total dissolved solids (TDS). Control of agricultural drainage in the San Joaquin Basin would result in lower concentrations in the San Joaquin River at Vernalis. Control of Sacramento Basin agricultural drainage may result in lower concentrations in the Sacramento River at Greene's Landing. However, due to Delta hydrology and the significant sources of TDS in Delta agricultural drainage and in seawater that intrudes into the Delta, it is unlikely that Sacramento Basin controls would significantly improve water quality at the Banks Pumping Plant. San Joaquin Basin controls would likely improve water quality at the Tracy Pumping Plant.

Nutrients. Of the three nutrients evaluated, it is likely that a reduction in ammonia concentrations at Greene's Landing could be achieved through control of the SRWTP effluent discharge. It is unlikely that significant reductions in the ammonia concentration at the Banks Pumping Plant would be achieved. Nitrate and phosphorus concentrations would not be reduced at the benchmark locations by controlling the discharges evaluated in this study.

Other Contaminants. There were sufficient data to examine a small subset of the list of contaminants of concern that was developed at the beginning of this study. It is possible that some of those contaminants might be found in significant concentrations in the discharges that were evaluated in this study and that control of those discharges might result in reduced concentrations at the benchmark locations. A substantial monitoring program would be required to evaluate the remaining contaminants.

Contaminant Source Characterization. The mass loading analysis showed for the most part that the loads of contaminants in the Sacramento River at Greene's Landing can not be easily attributable to discrete sources such as the SRWTP or the Colusa Basin Drain and Sacramento Slough. There may be many diffuse sources of contaminants in the Sacramento Basin that are not easily controlled. In the San Joaquin Basin, control of the agricultural drainage entering the San Joaquin River via Mud and Salt sloughs would result in lower TDS concentrations in the San Joaquin River at Vernalis. Due to Delta hydrology, improving the quality of the San Joaquin River would have limited, if any, impact on drinking water quality at the Banks Pumping Plant; however, water quality may be improved at the Tracy Pumping Plant.

INTRODUCTION

At the July 26, 1994 PAC meeting, the PAC and the project team concurred on the contaminants, locations, and mass loads methodology to complete the mass loads work for Phase I of the Study of Drinking Water Quality in Delta Tributaries. The objective of the mass loads work is to determine if alternative management of sources of key drinking water contaminants in the Delta tributary watersheds could significantly improve water quality in the Delta. This would be accomplished by examining the effect of these loads on the Delta tributary rivers.

Preliminary management alternative concepts for watershed contaminant sources include:

1. Rerouting Sacramento basin agricultural drainage into the Yolo bypass. The Colusa Basin Drain discharges into the Sacramento River upstream of the Fremont Weir intake to the Yolo bypass. The much larger capacity Sacramento Slough discharges to the Sacramento River on the opposite least) bank just upstream of Fremont Weir.

2. Reducing the contaminant load in Sacramento urban runoff discharges. The County and City of Sacramento are currently implementing best management practices to reduce contaminant loads.

3. Eliminating combined sewer overflows from the Sacramento Urban area.

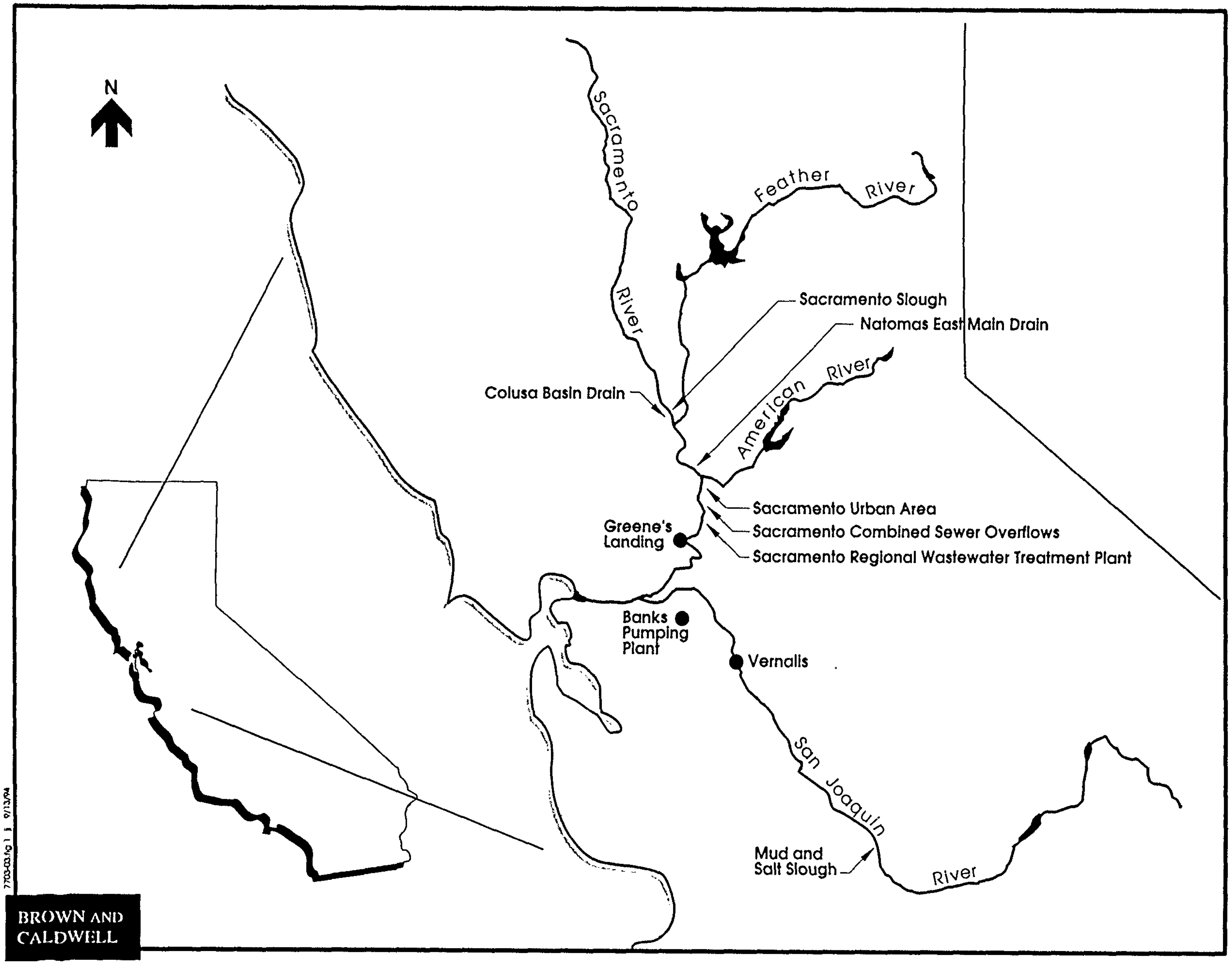
4. Diverting the SRWTP effluent discharge to a location downstream of the Delta Cross Channel.

5. Removing Mud and Salt sloughs drainage from the San Joaquin system.

The first four discharges listed above contribute contaminants to the Sacramento River. Mud and Salt sloughs (the fifth discharge listed) contribute contaminants to the San Joaquin River.

The PAC requested that load calculations be made and evaluated for organic carbon, bromide, alkalinity, TDS, selected nutrients, and arsenic. The Sacramento River at Greene's Landing, the San Joaquin River at Vernalis, and the Banks Pumping Plant in the south Delta were selected as the benchmark in-stream locations to be evaluated. Loads were not calculated, however, for the Banks Pumping Plant. Concentration data are graphed and discussed instead. For Banks Pumping Plant, the loads calculations would have reflected transfer out of the Delta as the flow data would be based on pumping records. All source discharges were selected for evaluation. The benchmark and discharge locations are shown on Figure 1.

The method used and discussed in this technical memorandum consists of two techniques. The first technique, requested by the PAC, involves constructing and evaluating time-series plots for rainfall, flow, concentration, and loads. These plots allow for a direct comparison of seasonal and historical patterns and allow for a direct and detailed examination of periods when



Legend:

- Benchmark
- Discharge Location

Figure 1. Benchmark and Discharge Locations

concentrations are high. The project team has supplemented these graphs with a second technique which involves combining data from four different sets of conditions/types of seasonal periods to calculate average loads. The four periods are: wet year/wet season, wet year/dry season, dry year/wet season, and dry year/dry season. This technique yields an estimate of the proportion of the load contributed by the various sources for the key contaminants under these four different periods, and thus allows more for a preliminary assessment of the effectiveness of management alternatives. For the purposes of this study, wet year is defined as any above normal or wet water year and dry year is defined as any below normal, dry, or critical water year. The wet season is defined as December through April when most rainfall occurs and the dry season is defined as May through November.

This technical memorandum consists of four sections. The first section describes the data used in the evaluation; the second section describes the methodologies used; the third section presents the results of the evaluation; and the fourth section summarizes the findings and conclusions of significance to water utilities. Much of the supporting material, consisting of the time-series plots and loads calculations, is appended.

SELECTED DATA

The Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) monitoring data were selected as the "base" water quality data set for this evaluation. The MWQI data, collected from water year 1990 to the present, constitute the most comprehensive data collected at the benchmark locations. Data from other monitoring programs were selected for the same period of record, i.e., from water year 1990 to water year 1993 in order to minimize differences in comparing different water years. Several monitoring programs have involved data collection prior to 1990, notably the East Bay Municipal Utilities District (EBMUD), U.S. Geological Survey (USGS), and DWR Operations and Maintenance monitoring programs which have collected earlier data at the three benchmark locations selected for evaluation. With the exception of Mud and Salt sloughs, and (for ammonia), the SRWTP, the data for the discharges evaluated has only been collected since 1990. Selected water quality data used in this study are shown in Table 1.

Data from water years 1990 to 1992 are grouped to represent the dry year period. The wet year period is represented by water year 1993 data.

Some assumptions were made in the treatment of the selected data:

Table 1. Water Quality Data Selected for Evaluation

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Benchmark location	Contaminant (data source: period of record)							
	Organic carbon	Bromide	Alkalinity	TDS	Nitrate	Phosphorous	Ammonia	Arsenic[a]
Banks Pumping Plant[b]	MWQI 90-93	MWQI 90-93	MWQI 90-93	MWQI 90-93	DWR/OMP 90-93	DWR/OMP 90-93	DWR/OMP 90-93	MWQI 90-93
Sacramento River, Green's Landing	MWQI 90-93	MWQI 90-93	MWQI 90-93	MWQI 90-93	EBMUD 90-91	--[c]	EBMUD 90-91	MWQI 90-93
Sacramento River, Freeport[d]						USGS 90-93		
San Joaquin River, Vernalis	MWQI 90-93	MWQI 90-93	MWQI 90-93	MWQI 90-93	USGS 90-93	USGS 90-93	USGS 90-93	USGS 90-93
Discharge location								
Natomas East Main Drain[e]	MWQI 90-93	MWQI 90-93	MWQI 90-93	MWQI 90-93	--[c]	--[c]	--[c]	--[c]
Sacramento Urban Runoff	--[c]	--[c]	--[c]	90-92	90-92	90-92	90-92	90-92
Sacramento Combined Sewer Overflow	--[c]	--[c]	--[c]	91-93	91-93	91-93	91-93	91-93
Sacramento Regional Wastewater Treatment Plant	ERWQA 91-93	--[c]	--[c]	ERWQA 91-93	--[c]	--[c]	ERWQA 91-93	ERWQA 91-93
Mud and Salt Sloughs	86-88	--[c]	86-88	86-88	86-88	86-88	86-88	86-88

[a]Loads not calculated for arsenic as most data was reported as non-detected or detected in a very narrow range just above the detection limits. Concentrations of arsenic are discussed.
[b]Loads not calculated for Banks Pumping Plant as "flow" data would yield artificial loads. Concentrations are graphed and discussed.
[c]No data identified.
[d]The Sacramento River at Freeport is used as a surrogate for the Sacramento River at Greene's Landing for phosphorous. Greene's Landing is 8 miles downstream of Freeport.
[e]Natomas East Main Drain is used as a surrogate for Colusa Basin and Sacramento Slough. Natomas East Main Drain receives rice field drainage from north of the Sacramento urban area but also receives some Sacramento urban runoff.

Key to abbreviations:

TDS	=	Total dissolved solids.
MWQI	=	Municipal Water Quality Investigations.
DWR/OMP	=	Department of Water Resources Operations Monitoring Program.
EBMUD	=	East Bay Municipal Utility District.
USGS	=	United States Geological Survey.
ERWQA	=	Effluent and Receiving Water Quality Assessment.

1. The Sacramento River at Freeport is used as a surrogate for the Sacramento River at Greene's Landing for phosphorus. There were no phosphorus data identified for Greene's Landing. Freeport, about 8 miles upstream of Greene's Landing, is upstream of the SRWTP discharge.

2. The Natomas East Main Drain MWQI data were used as a surrogate for Colusa Basin Drain and Sacramento Slough water quality. The Natomas East Main Drain receives rice field drainage from the area immediately north of the Sacramento urban area. The drain also receives some Sacramento urban runoff. The data from the few samples collected from Colusa Basin Drain and Sacramento Slough by the DWR Northern District indicated that concentrations of the key contaminants are comparable to the Natomas East Main Drain concentrations.

3. An exception to the 1990-1993 period of record was made for Mud and Salt sloughs. Organic carbon and total dissolved solids loads were calculated for Mud and Salt sloughs during the period 1986 to 1988 because there were no more current adequate data identified for these agricultural drains and the evaluation of these two contaminants provided for a gross evaluation of the significance of this drainage. Thus, Mud and Salt sloughs loads from 1986 to 1988 are compared to the loads at the San Joaquin River at Vernalis from 1990 to 1993.

4. No data were examined with regard to quality assurance/quality control (QA/QC) considerations. These data were accepted as correct and meeting acceptable QA/QC standards by each reporting agency. The majority of the data are from the DWR MWQI program. The MWQI QA/QC program has been approved by many of the PAC members.

5. The comparison of the autosampler data to the monthly grab data at Greene's Landing illustrates how the wet season peaks are missed by sampling programs without daily sampling frequency (most sampling programs). It is likely that wet season concentrations and loads, in general, are underestimated. Data used in this study were collected on mostly a monthly frequency. The implicit assumption that these data are representative may be incorrect for wet season periods.

Flow data consisted of information collected during the same time period as the water quality data from the following sources:

1. DWR: Dayflo mean daily flows at the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis for MWQI water quality data comparisons and calculations.

2. USGS: Stream gage data for Freeport, Vernalis, and Mud and Salt sloughs for USGS water quality data comparisons and calculations.

3. Sacramento County Effluent and Receiving Water Quality Assessment (ERWQA): SRWTP flow data effluent discharge quantities for ERWQA SRWTP water quality data comparisons and calculations.

4. DWR Northern District: Colusa Basin Drain and Sacramento Slough flow data for MWQI Natomas East Main Drain water quality comparisons and calculations.

Flow data were not available for Sacramento urban runoff or Sacramento combined sewer overflows. However, estimates of the total volume discharged during some years within our period of evaluation (1990-1993) were available from City of Sacramento reports.

Rainfall data are from a rain gage in Stockton which is the rainfall station used in the DWR Dayflo database program.

METHODOLOGY

The time-series graphs show rainfall, flow, and contaminant concentrations for the benchmark locations and discharges. The companion load graphs were produced by performing the following calculation:

$$\text{Mass load (lbs. per day)} = Q \times C \times 8.34$$

where

Q, the flow in million of gallons per day (mgd) = Q (cfs) x 0.64632

C, is the contaminant concentration in milligrams per liter (mg/l),

or

$$\text{Mass load} = \text{Flow (cfs)} \times 0.64632 \times 8.34 \text{ lbs/gal} \times C \text{ (mg/l)}$$

To obtain loads for the four periods (e.g., dry year/dry season, etc.) the average loads of each contaminant were calculated for each period. Some periods had more data points than others.

There were insufficient data to graph loads for Sacramento urban runoff or Sacramento combined sewer overflows. Mud and Salt slough loads, which are outside the main period of record evaluated in this study, were also not graphed. Loads for these discharges were determined based on the specific type and amount of available data. Load calculation methods for these three discharges are discussed in more detail in Appendix A.

MASS LOADING RESULTS

The mass loading analysis, presented below for each contaminant, is based on the detailed time series plots (Appendices B through J) and the contaminant loading analysis during the four specified periods (dry year/dry season, etc.) The range of concentration data are presented in tables in the body of the memorandum. The comparisons made in conducting this analysis are discussed below.

Rainfall Versus Flow Time Series Plots

The DWR Dayflo model rainfall data were plotted over time (time-series) and compared to time series plots of river flow data. The comparisons were used to discriminate between high river flow events due to rain versus those caused by upstream reservoir releases and/or watershed discharges. However, since the Dayflo rain data are based on measurements at a Stockton fire station, which is downstream of both the Greene's Landing and Vernalis stations, there are times when upstream rain fall events do not coincide with rain events observed at Stockton. In general, there did seem to be good agreement with the timing of major storms (measured in Stockton) with peak flow observed at Greene's Landing and Vernalis.

Contaminant Concentration Time Series Plots

Concentration plots of contaminants at the benchmark locations were plotted over time and compared to the rainfall, river flow, and watershed discharge time series plots. These comparisons were made to see if the changes in concentrations consistently correlated with storm events, river flows, or watershed discharges.

Contaminant Mass Load Time Series Plots

The mass load of contaminants at the benchmark locations were computed and plotted over time. The results were compared to the preceding time series plots for rain fall, river flows, watershed discharges, and benchmark contaminant concentrations. Since mass loads correlate highly with flow, the time series plots of the two were nearly identical. The occasions when there were disagreements in the trends, such as an increase in the mass load of a contaminant during an observed decrease in flow, may indicate an upstream discharge of the contaminant at a high concentration. Some increases may be from within the river channels. For example, organic carbon increases may be caused by such events as algal blooms, sediment leaching, riparian vegetation, and wind blown deposits. Decreases in some chemical contaminants could be caused by biological and chemical removal within the river channels. In either case, the comparisons indicate time periods to investigate for sources of upstream contamination.

Discharge Loads

Comparisons within the two Delta tributary watersheds (the Sacramento and San Joaquin rivers' watersheds) are also based on loads of the discharges compared to the downstream benchmark location (either the Sacramento River at Greene's Landing or the San Joaquin River at Vernalis) for the four periods.

Benchmark Comparisons

Loads and concentrations of contaminants at Greene's Landing and Vernalis are compared to assess the relative significance of the riverine sources with respect to the contaminants evaluated. In-Delta sources and San Francisco Bay/seawater sources are discussed but were not evaluated for this study. Also, eastside tributary streams (Calaveras, Cosumnes, and Mokelumne rivers) were assumed negligible since the eastside streams contribute less than 1 percent of the flow to the Delta.

The discussion below is individual to each contaminant.

Organic Carbon

Total organic carbon concentrations in source water will be regulated in Stage 1 of the Disinfectants-Disinfection By-Products (D-DBP) Rule. Under Stage 1, a treatment technique requirement will be established for removing DBP precursors. By removing these organic precursors, the formation of known and unknown disinfection by-products can be lowered to meet maximum contaminant levels (MCLs) for total trihalomethanes (TTHMs) and haloacetic acids (HAA5) under the D-DBP Rule.

Since direct measurement of DBP precursors is not practical, total organic carbon (TOC) concentrations will be used as a surrogate measurement. Lower TOC will result in lower organic compounds and yield lower DBP formation.

The Stage 1 precursor-removal requirements will apply only to conventional water treatment plants and to softening plants. Enhanced coagulation or softening will be required for these systems to comply with specified percentages of TOC removal prior to adding disinfectant. The specified percentage of TOC removal will be based on the source water TOC and alkalinity. Under the D-DBP Rule the anticipated percent removal of TOC required by enhanced coagulation are shown below in Table 2.

Table 2. Anticipated Percent Removal of TOC Required by Enhanced Coagulation

Source water TOC, mg/l	Source water alkalinity, mg/l		
	0-60	>60-120	>120[a]
≥2-4	40%	30%	20%
>4-8	45%	35%	25%
>8	50%	40%	30%

[a]Systems practicing softening must meet TOC removal requirements in this column.

Dissolved organic carbon (DOC) concentration data and computed loads from the benchmark locations, Sacramento and Colusa Basin drain agricultural drainage, and TOC concentration data and computed loads for the SRWTP were graphed as time-series plots. In addition, autosampler data (with a daily sampling frequency) for the Sacramento River at Greene's Landing and specific absorbance for the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis were graphed as time-series plots. Regression plots of flow versus load were also developed for the Sacramento River at Greene's Landing. These plots are in Appendix C. A table showing the range of DOC and TOC concentrations at the benchmark locations and in the discharges was developed (Table 3) and a figure showing the relative proportions of DOC and TOC at the benchmarks and in the discharges was constructed (Figure 2). Both DOC data and TOC were used in the evaluation. As most organic carbon is in dissolved form, this should not significantly affect the evaluation.

Table 3. Range of Organic Carbon Concentrations[a]

Location	Range of concentration, mg/l[b]
Banks Pumping Plant (1990-1993)	2.6-10.5
Sacramento River at Greene's Landing (1990-1993)	1.4-5.7
Natomas East Main Drain (1990-1993)	3-9.3
Sacramento Slough and Colusa Basin Drain (1990-1993)	1.9-5.7
Fresno Urban Runoff (1981-1983)	4.4-550
SRWTP (1990-1993)	3-42
San Joaquin River at Vernalis (1990-1993)	2.2-11.4
Mud and Salt sloughs (1986-1988)	5.5-31

[a]All concentrations are for DOC except SRWTP effluent and Mud and Salt sloughs which are TOC data.
[b]Concentration range of residential urban runoff. No Sacramento urban runoff organic carbon data have been collected.

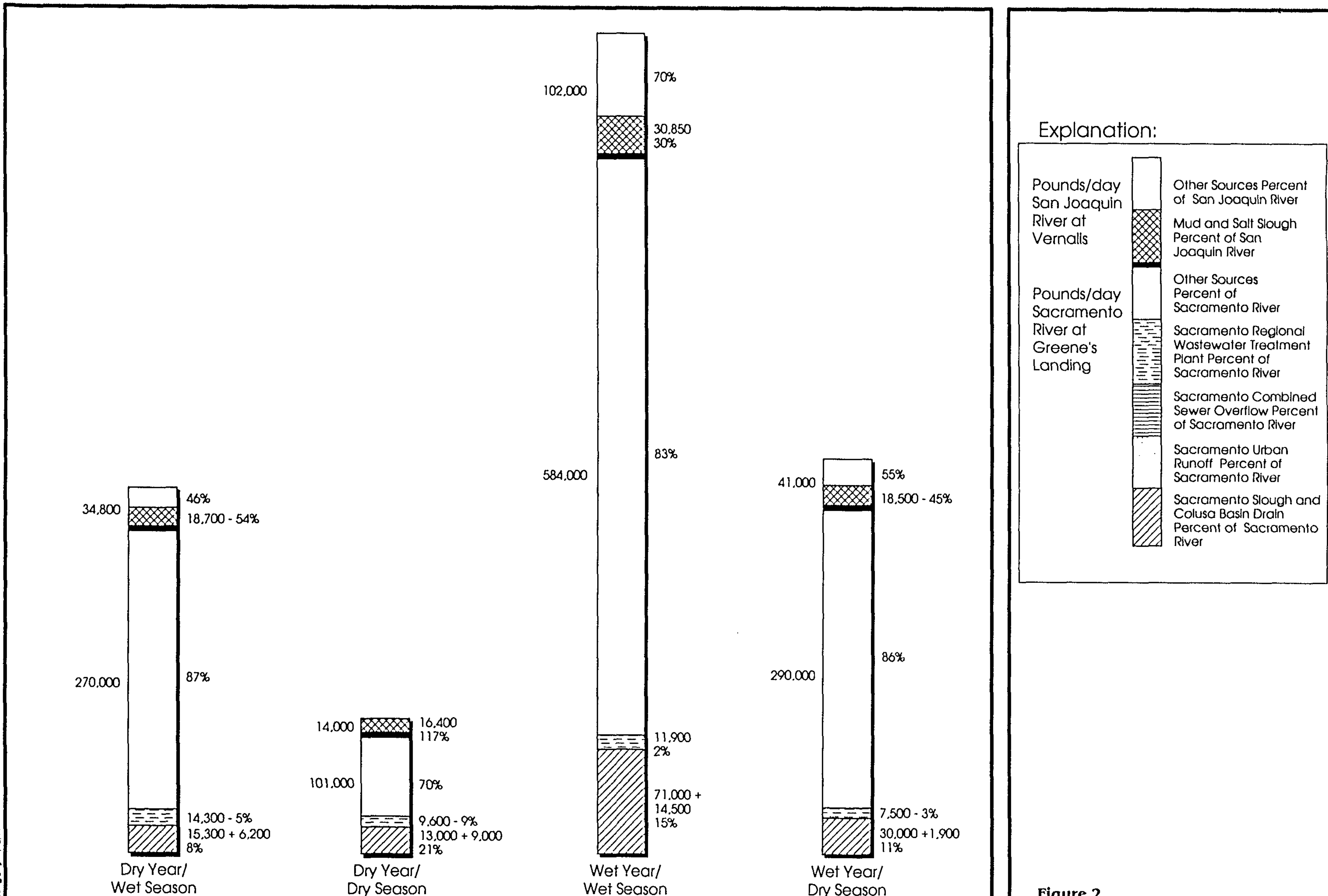

Figure 2.
Relative Contribution of Organic Carbon from the Delta Tributaries

BROWN AND CALDWELL

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Data Analysis. The data analysis, based on the materials referenced above, is presented in a question and answer format.

How do concentrations compare, seasonally, between Banks Pumping Plant and the two tributary benchmark locations (the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis)?

Concentrations at Banks Pumping Plant range from 2.6 to 10.5 mg/l. These concentrations are comparable to the San Joaquin River at Vernalis (2.2 to 11.4 mg/l) but about half that of the Sacramento River at Greene's Landing (1.4 to 5.7 mg/l). Wet season concentrations at all three benchmark locations are considerably higher and more variable than during the dry season. The autosampler data at Greene's Landing shows that monthly dry weather samples are representative of dry weather concentrations. Wet weather concentrations, however, are underestimated in the monthly data (the data necessarily used in this study). The wider range of DOC concentrations during the wet season usually occurred briefly over a day or two and indicates short pulses of organic material passing through Greene's Landing after a storm.

What are the concentration trends at the upstream discharges?

At the Natomas East Main Drain, DOC levels were the highest (above 6 mg/l) in the late fall and early winter months. These high concentrations probably reflect the combined effects of rainfall, surface runoff, and decaying vegetation (crops and riparian) in the fields and drainage ditches. Summer DOC generally ranged from 4 to 5 mg/l. Concentrations in the SRWTP effluent discharge were fairly constant at about 12 to 18 mg/l with an overall range of 3 to 42 mg/l.

What are the differences in specific absorbance between the two tributary benchmark locations?

Humic substances in water, when chlorinated, lead to the formation of trihalomethanes. Most humic substances strongly absorb ultraviolet light at the 254 nm wavelength. This physical characteristic is useful in assessing the THM precursor potential of organic carbon in water supplies. To assess the relative amount of precursor or humic material in water, the UV-254 nm absorbance is compared to the DOC concentration of a water sample. This ratio is called the specific absorbance.

In general, the specific absorbances of agricultural drainage from organic soils in the Delta are 0.03 and higher. When the specific absorbance of river water samples approach 0.03, it is usually an indication of increasing amounts of surface water runoff and/or drainage water in the channels.

There appears to be little difference in the specific absorbance at the two Delta tributary benchmark locations. The specific absorbance at both locations frequently reaches 0.03.

What is the relationship between load and flow at the Sacramento River at Greene's Landing?

There is a very good correlation between load and flow when flow is below about 50,000 cubic feet per second (cfs). Anomalously high loads occur during the wet season.

How do loads entering the Delta compare between the two tributary benchmark locations?

The Sacramento River contributes approximately 85 to 89 percent of the riverine Delta load and the San Joaquin River contributes 11 to 15 percent. The San Joaquin River contributes organic carbon in a slightly higher proportion than its flow contribution which is roughly 10 percent.

How do loads compare between the tributary benchmark locations and their upstream discharges?

Due to a lack of DOC data for Sacramento Slough and Colusa Basin Drain, the data from Natomas East Main Drain were used as a surrogate. The limited DOC data from Sacramento Slough and Colusa Basin Drain were comparable, however, to the Natomas East Main Drain data. Mass load calculations were based on the monthly Natomas East Main Drain DOC data and recorded flows at Sacramento Slough and Colusa Drain. Mass loads at these two upstream sites are underestimated as no flows were reported when flooding occurred at the gaging stations. Flooding generally occurred in March and April. In the Sacramento Basin, Sacramento Slough and Colusa Basin Drain are estimated to contribute at least 8 to 21 percent of the organic carbon load and the SRWTP is estimated to contribute 2 to 9 percent. Other unidentified sources contribute 70 to 87 percent of the load. These other sources include Sacramento urban runoff (since it was not possible to calculate that load for this study). Based on the range of DOC concentrations (4.4 to 550 mg/l) measured in Fresno urban runoff in the early 1980s, it may be that Sacramento urban runoff constitutes a considerable portion of the unidentified organic carbon load. The impact of a heavy storm (March 1992) on TOC in the treated effluent discharged by the SRWTP is evident in the time series concentration graph. On March 29, 1992, the DOC concentration was about 42 mg/l, which was about 30 mg/l higher than other time periods. This increase may be attributable to high volumes of combined sewer system stormwater runoff entering the plant.

In the San Joaquin Basin, Mud and Salt sloughs are a significant proportion of the overall organic carbon load. The percentages shown on Figure 2 can only be considered rough estimates as the discharge data and river data are not from the same period of record. Although Mud and Salt sloughs constitute a significant proportion of the San Joaquin River load, the entire San Joaquin River load is less than 15 percent of the total riverine load.

The data show that the sources for the major proportion of organic carbon loads in the Sacramento basin have not been identified. Relative to these unknown sources, which may include in-channel production (e.g., algae, riparian vegetation), the discharge sources evaluated for this study (with the possible exception of urban runoff) are less significant.

A significant, and perhaps the major source or organic carbon load to the San Joaquin basin, comes from Mud and Salt sloughs. This load may reflect, at least in part, the recirculation of Delta water through Mud and Salt sloughs in agricultural irrigation runoff.

In summary, it does not appear that the control of the studied upstream discharge sources will alone cause significant reductions in the TOC concentrations at Banks Pumping Plant.

Alkalinity

The alkalinity of water is not a human health concern but may be important in determining the level of TOC removal in source water at water treatment facilities as required by the D-DBP Rule.

Alkalinity concentrations at the benchmark locations and Natomas East Main Drain were graphed as time-series plots (Appendix D) and the range of concentrations at the benchmark locations and in the discharges were tabulated (Table 4). Mass load calculations for alkalinity were not performed for the following reasons:

1. Be definition, alkalinity in water is the capacity of that water to neutralize acids. While alkalinity may be comprised of a number of salts of weak acids, bicarbonates are by far the major form of alkalinity in ground and surface waters. Above a pH of 8.3, hydroxide alkalinity becomes important. Unlike the other parameters selected for determining mass loadings, alkalinity is a parameter that exists as a result of its analytical definition. Alkalinity is measured by titrating

an acid into the sample until an end point (defined by a color change at a pH value) is reached.

2. Alkalinity is not a conservative substance. It can be affected by the introduction of carbon dioxide into water or the stripping of carbon dioxide from water. Algae activity and resultant respiration can increase carbon dioxide during the night, depress the pH, and reduce the water's alkalinity. The reverse can happen during the day when photosynthesis utilizes carbon dioxide.

3. Further, there are no "sources" of alkalinity at are controllable. It may be that there are sources of acid mine drainage in the Sacramento River that reduce alkalinity and contribute to its variability, but the sources are uncontrollable (McGuire, 1993).

Table 4. Range of Alkalinity Concentrations

Location	Concentration, mg/l
Banks Pumping Plant (1990-1993)	47-96
Sacramento River at Greene's Landing (1990-1993)	38-79
Natomas East Main Drain (1990-1993)	51-314
Fresno Urban Runoff (1981-1983)	1-257
San Joaquin River at Vernalis (1990-1993)	53-155
Mud and Salt sloughs (1986-1988)	123-370

Data Analysis. The data analysis is based on the materials referenced above and on Table 2, Anticipated Percent Removal of TOC Required by Enhanced Coagulation.

How do concentrations compare, seasonally, at the benchmark locations and the discharges?

Alkalinity concentrations at Banks Pumping Plant (47 to 96 mg/l) are intermediate between those at the Sacramento River at Greene's Landing (38 to 79 mg/l) and the San Joaquin River at Vernalis (53 to 155 mg/l). Alkalinity measurements for the discharges have a much greater range with 51 to 314 mg/l measured at Natomas East Main Drain, 1 to 257 mg/l measured in Fresno urban runoff, and 123 to 370 mg/l in Mud and Salt sloughs. No apparent seasonal trends in alkalinity concentrations were evident in the time-series plots.

What is the expected range of TOC removal that might be required for source water at the benchmark locations?

The required range of percent TOC removal, based on the range of organic carbon and alkalinity concentrations at the benchmark locations would be:

Banks Pumping Plant:	30 to 40 percent
Sacramento River at Greene's Landing:	30 to 35 percent
San Joaquin River at Vernalis:	20 to 30 percent

There are no upstream alternatives that can effectively control the alkalinity of natural waters above and in the Delta.

Bromide

Bromide concentrations in raw water supplies are a drinking water concern because of the formation of disinfection by-products such as haloacetic acids, bromate, and trihalomethanes. In the Delta, the major source is ocean water. Open ocean water contains about 65 mg/l of bromide. Bromide levels in the Sacramento River at Mallard Island have been observed as high as 23 mg/l and less than 1 mg/l depending on hydrologic conditions and tides.

Because of their locations, the bromide levels at the water intakes in the western Delta, such as at Clifton Court Forebay and at the Contra Costa Water District's Rock Slough intake, are subject to the effects of seawater intrusion and daily tidal excursions. Bromide levels at Greene's Landing, which is far upstream of the western Delta, are attributed to upstream sources. The sources of bromide in the San Joaquin River at Vernalis have not been definitively traced. However, the suspected sources include the drainage from areas of ancient marine deposits in the San Joaquin Valley and Delta water that is diverted to the valley for irrigation and recirculated through the San Joaquin River system.

The migration of bromide entering the Delta has been tracked by DWR's MWQI Program (DWR, 1993). Over 30 stations were sampled over a three-day period for bromide and chloride measurements. The data showed that the major bromide and chloride source to the Banks headworks was from seawater. The sources from bromide and chloride at the Tracy Pumping Plant were both seawater and the San Joaquin River (see Figure 3).

Currently, there is no drinking water standard for bromide. However, the MCL for bromate will be 0.010 mg/l in the D-DBP Rule. Bromate is a by-product of ozonation when bromide is present.

Bromide concentrations were graphed in time-series plots for the benchmark locations and Natomas East Main Drain (Appendix E) and the range of concentrations at the benchmark locations and in the discharges are shown in Table 5. Bromide loads were not calculated because the concentrations at the tributary benchmark locations are two to three orders of magnitude less than concentrations at Mallard Island which reflect seawater intrusion. Therefore, it was deemed not useful to estimate loads for such a potentially small portion of the total Delta bromide source.

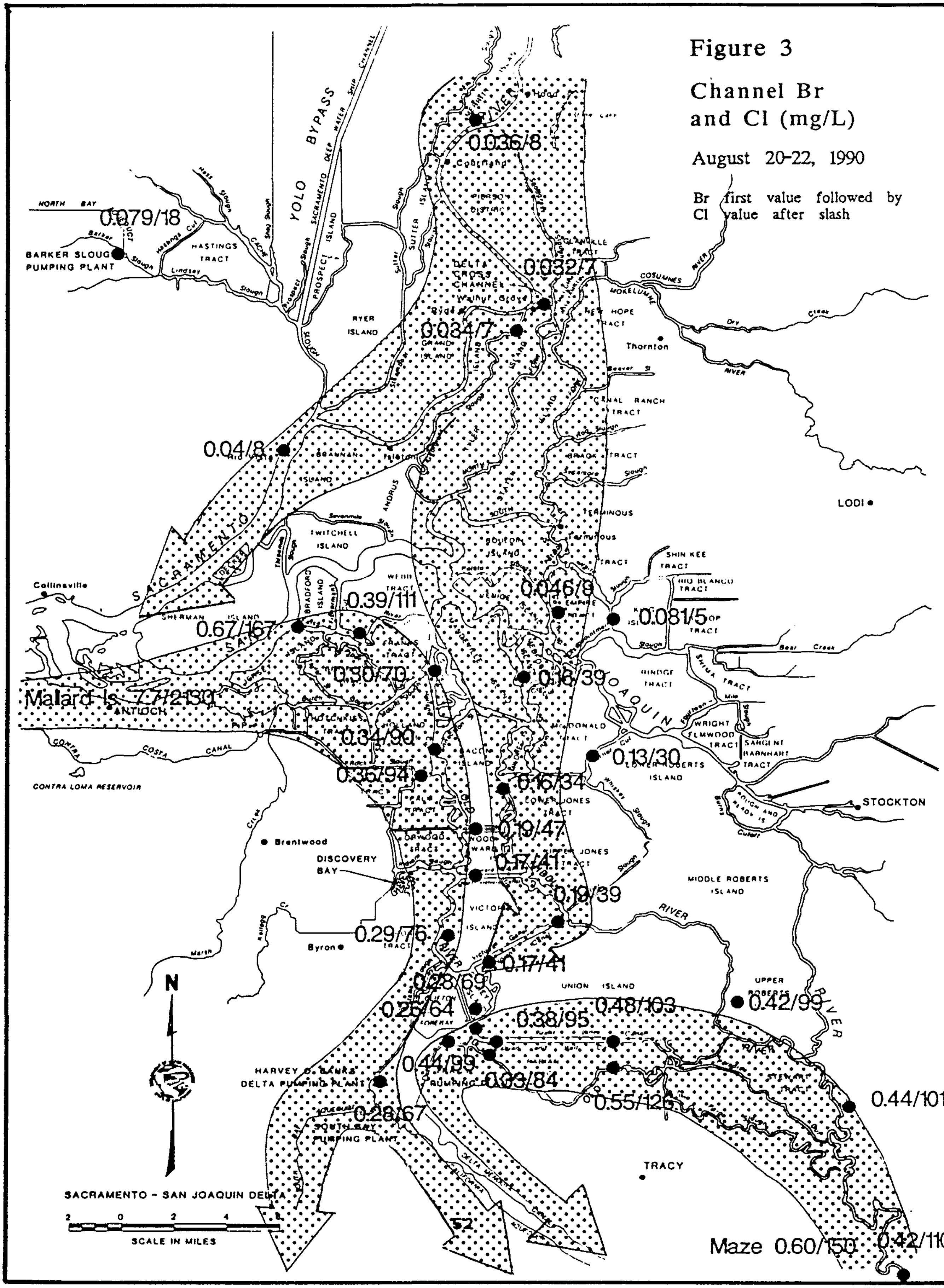

Figure 3

Channel Br and Cl (mg/L)

August 20-22, 1990

Br first value followed by Cl value after slash

Data Analysis. The data analysis is based on the materials referenced above.

How do concentrations compare, seasonally, at the benchmark and discharge locations?

Bromide concentrations at Banks Pumping Plant range from 0.05 to 0.65 mg/l. This is the same range as bromide concentrations in the San Joaquin River at Vernalis. concentrations in the Sacramento River at Greene's Landing (<0.01 to 0.05 mg/l) are an order of magnitude less. At Banks Pumping Plant, bromide concentrations were much higher during the dry years (January 1990 to November 1992) than in wet year 1993. Bromide levels were generally lowest in the spring months (March and April) of the dry years. The higher bromide levels reflect lower Sacramento River outflows to repel seawater migration into the western Delta. Bromide concentrations at Greene's Landing were mostly 0.02 mg/l with no apparent seasonal pattern. Bromide was often slightly higher (0.03-0.04 mg/l) in 1990 than in subsequent years. Vernalis bromide concentrations were higher during the dry years than in 1993. This may reflect the quality of Delta water that was diverted to the Central Valley for irrigation.

Natomas East Main Drain bromide concentrations range from 0.05 to 0.19 mg/l. There were no apparent seasonal trends at the benchmark locations or the Natomas East Main Drain.

The reduction of bromide concentrations at Greene's Landing does not appear to be controllable by managing upstream sources. The management of discharges upstream of the Delta would not significantly reduce bromide concentrations at the Banks Pumping Plant. The reduction of bromide concentrations in the western Delta, such as at the Banks Pumping Plant, will continue to depend on those operations of the State Water Project which influence the amount of seawater intrusion in the western Delta including upstream releases, the Delta cross channel gate operations, and operating procedures for the Clifton Court Forebay gates. Ocean water is the major source of bromides to the western Delta and difficult to control without continuous high Delta outflows or physical barriers.

Table 5. Range of Bromide Concentrations

Location	Concentration, mg/l
Banks Pumping Plant (1990-1993)	0.050-0.650
Sacramento River at Greene's Landing (1990-1993)	<0.01-0.05
Natomas East Main Drain (1990-1993)	0.05-0.190
Sacramento Slough and Colusa Basin Drain (1990-1993)	0.2
San Joaquin River at Vernalis (1990-1993)	0.050-0.650

Total Dissolved Solids

There are many sources of TDS to the Delta. Open ocean water TDS is about 35,000 mg/l. Agricultural drainage from Delta islands and tracts have TDS of several hundred mg/l to a few thousand mg/l. Major TDS sources, therefore, include seawater, connate water, runoff containing dissolved minerals, and agricultural drainage bearing soluble salts from irrigation water and leachate from the fields. The secondary U.S. Environmental Protection Agency (USEPA) Drinking Water Standard MCL for TDS is 500 mg/l. This MCL is based primarily on taste and odor considerations.

TDS concentrations and computed loads from the benchmark locations, Sacramento Slough and Colusa Basin Drain, and the SRWTP were graphed as time-series plots (Appendix F). A table showing the range of TDS concentrations at benchmark locations and in the discharges was developed (Table 6) and a figure showing the relative proportions of TDS at the tributary benchmark locations and in the upstream discharges was constructed (Figure 4).

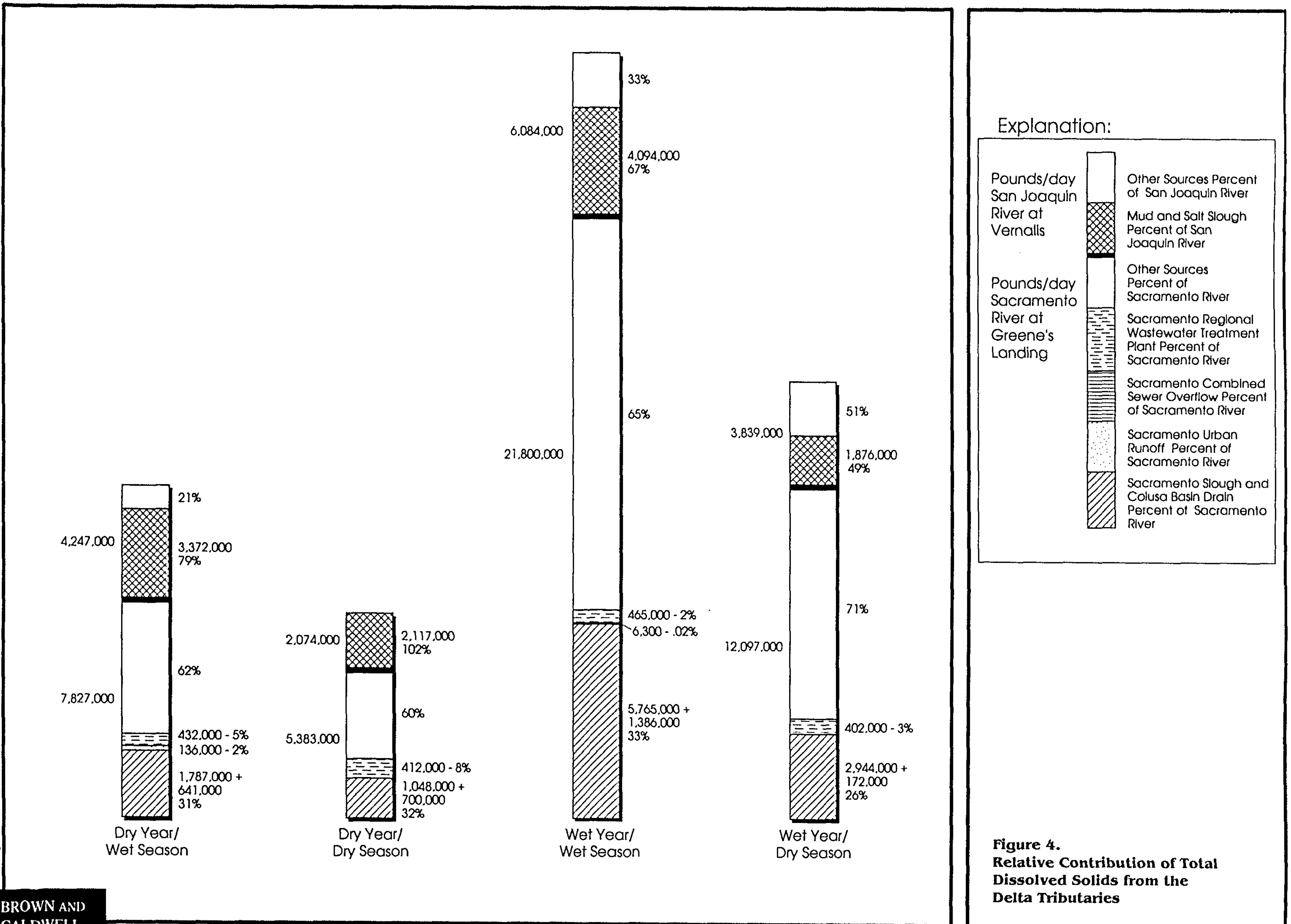

Figure 4.
Relative Contribution of Total Dissolved Solids from the Delta Tributaries

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Table 6. Range of Computed Total Dissolved Solids[a] Concentrations

Location	Concentration, mg/l
USEPA Drinking Water Standard Secondary MCL	500
Banks Pumping Plant (1990-1993)	44-417
Sacramento River at Greene's Landing (1990-1993)	39-132
Natomas East Main Drain (1990-1993)	225-674
Sacramento Slough and Colusa Basin Drain (1990-1993)	70-314
Sacramento Urban Runoff (1990-1993)	22-440
Sacramento Combined Sewer Overflow (1990-1993)	50-300
SRWTP (1990-1993)	422-666
San Joaquin River at Vernalis (1990-1993)	143-768
Mud and Salt sloughs (1986-1988)	483-5,180

[a]Most values are computed from electrical conductivity measurements. Exceptions are Sacramento urban runoff, Sacramento combined sewer overflow, and Mud and Salt sloughs. These data are laboratory analytical results for TDS.

Data Analysis. The data analysis was based on the materials referenced above.

How do concentrations compare seasonally between Banks Pumping Plant and the two Delta tributary benchmark locations?

TDS concentrations at Banks Pumping Plant (44 to 417 mg/l) are intermediate between concentrations in the Sacramento River at Greene's Landing (39 to 132 mg/l) and the San Joaquin River at Vernalis (143 to 768 mg/l). No significant seasonal trends were apparent.

How do flows correlate to concentration at the two Delta tributary benchmark locations?

Concentrations in the Sacramento River at Greene's Landing do not appear related to flow. At the San Joaquin River at Vernalis, there is an inverse relationship, the higher the flow, the lower the concentration. This likely reflects the dilution of the main stem of the San Joaquin River (primarily Mud and Salt slough flows) with fresh eastside tributary (Merced, Tuolumne, and Stanislaus rivers) flows during the wet season. Peak summer TDS concentrations generally occurred in July, the peak irrigation month and usually the highest temperatures. Late fall and early winter TDS increases may relate to drainage from fields being leached of the preceding summer salt deposits.

What are the concentration trends in the upstream discharges?

Discharge concentrations in Natomas East Main Drain (225 to 674 mg/l) are much lower than in San Joaquin basin agricultural drainage (483 to 5,180 mg/l). Sacramento urban runoff (22 to 440 mg/l) and Sacramento combined sewer overflow (50 to 300 mg/l) have similar concentrations. The SRWTP has a relatively narrow range of concentrations in its effluent (422 to 666 mg/l). Natomas East Main Drain TDS concentrations seemed to show higher levels in the fall and winter than during the summer. This may reflect the leaching of salt deposits from the fields from rainfall or irrigation. In most cases, TDS concentrations at the SRWTP were 500 to 600 mg/l. The lowest observed TDS concentrations (about 420 mg/l) occurred during December 1992 and January 1993, a period of heavy rainfall.

How do loads entering the Delta compare between the two tributary benchmark locations?

The Sacramento River is estimated to contribute 65 to 78 percent of the riverine TDS load to the Delta. The San Joaquin River is estimated to contribute 22 to 35 percent of the load, which is about two to three times its flow contribution.

How to loads compare between the tributary benchmark locations and their upstream discharges?

Sacramento Slough and Colusa Basin Drain agricultural drainage are estimated to contribute 26 to 33 percent of the TDS load in the Sacramento River at Greene's Landing.

Sacramento urban runoff, Sacramento combined sewer overflow, and the SRWTP each contribute about 2 percent of the TDS load in the Sacramento River.

Mud and Salt sloughs contribute upwards of half the TDS load to the San Joaquin River at Vernalis. The percent contributions shown on Figure 4 can only be considered rough estimates as the discharge data and river data are not from the same period.

Overall, agricultural drainage from Mud and Salt sloughs and from Sacramento and Colusa Basin Drain are estimated to contribute 30 to 50 percent of the riverine TDS load to the Delta. Other significant sources are diffuse and/or unidentified. Alternative management of agricultural drainage sources could be expected to lower TDS concentrations at their respective downstream tributary benchmark locations, particularly at Vernalis. It is not known whether this would affect concentrations at Banks Pumping Plant due to the considerable TDS contribution from in-Delta and seawater sources.

Arsenic

The current USEPA recommended MCL is 0.05 mg/l. However, because arsenic is classified by the USEPA as a human carcinogen, a proposed maximum contaminant level goal (MCLG) of zero is expected in accordance with the agency's policy. Current data suggest the MCLG would be likely set at less than 0.010 mg/l if based on noncancer effects.

The MCL must be set as close to the MCLG as feasible, based on best available technology (BAT) and cost considerations. This means that the MCL will be set at the practical quantitation level (PQL of 0.002 to 0.005 mg/l) if USEPA determines that available treatment can lower arsenic concentrations to below the PQL. If treatment below the PQL is not feasible, then the MCL will be based on BAT results.

Arsenic is the twentieth most common element in the earth's crust and therefore, widely distributed. This observation is supported by the generally even distribution of arsenic at all the benchmark locations.

Arsenic concentration data were graphed as a time-series plot only for the SRWTP (Appendix G). Ranges of arsenic concentrations for the benchmark locations and discharges are shown in Table 7. Loads were not calculated for arsenic. The reason is that because the range of arsenic is so similar at the benchmark and discharge locations, these graphs would have been near reflections of the flow graphs. Additionally, the similarity of the concentrations means that reducing concentrations through controlling the discharges being studied is not realistic. Arsenic concentrations in the mg/l range have been identified in mine drainage from the Yuba and Bear river watersheds of the Sacramento basin. This was discussed in Technical Memorandum 2A. However, there are insufficient data from the mine drainage source to calculate loads or graph concentrations from this source.

Table 7. Range of Arsenic Concentrations

Location	Concentration, µg/l
USEPA Drinking Water Standard Primary MCL	50
Banks Pumping Plant (1990-1993)	2-3
Sacramento River at Greene's Landing (1990-1993)	1-2
Sacramento Slough and Colusa Basin Drain (1990-1993)	3-9
Sacramento Urban Runoff (1990-1993)	<2-5
Sacramento Combined Sewer Overflow (1990-1993)	0.5-5
SRWTP (1990-1993)	<0.6-3.4
San Joaquin River at Vernalis (1990-1993)	1-3
Mud and Salt sloughs (1986-1988)	2-11

Data Analysis. The data analysis is based on the materials referenced above.

How do the concentrations compare at the benchmark and discharge locations?

Arsenic concentrations at all three benchmark locations are within the 1 to 3 micrograms per liter (µg/l) range. Concentrations in the discharges are in the <0.6 to 11 µg/l range. Due to its ubiquitous presence, it appears that none of the proposed alternatives for upstream water management could cause any significant decreases in arsenic concentrations.

Nutrients

Ammonia, nitrate, and total phosphorus were the nutrients selected for evaluation. Nutrients can contribute to algal blooms in source waters. Of these three nutrients, only nitrate has a drinking water standard (10 mg/l nitrate and nitrite as nitrogen).

Ammonia concentration and computed loads for the three benchmark locations and the SRWTP were graphed as time-series plots (Appendix H). Nitrate and total phosphorus concentrations were graphed as time-series plots (Appendices I and J, respectively). Ranges of concentrations for all three nutrients for the benchmark locations and the discharges are shown in Tables 8, 9, and 10, respectively. Relative contributions of ammonia loads are shown on Figure 5.

Table 8. Range of Dissolved Ammonia Concentrations

Location	Concentration, mg/l
Banks Pumping Plant (1990-1993)	0.01-0.72
Sacramento River at Greene's Landing (1990-1993)	0.01-0.9
Sacramento Urban Runoff (1990-1993)	0.3-0.78
SRWTP (1990-1993)	9.5-21.0
San Joaquin River at Vernalis (1990-1993)	0.01-0.28
Mud and Salt sloughs (1986-1988)	0.03-2.1

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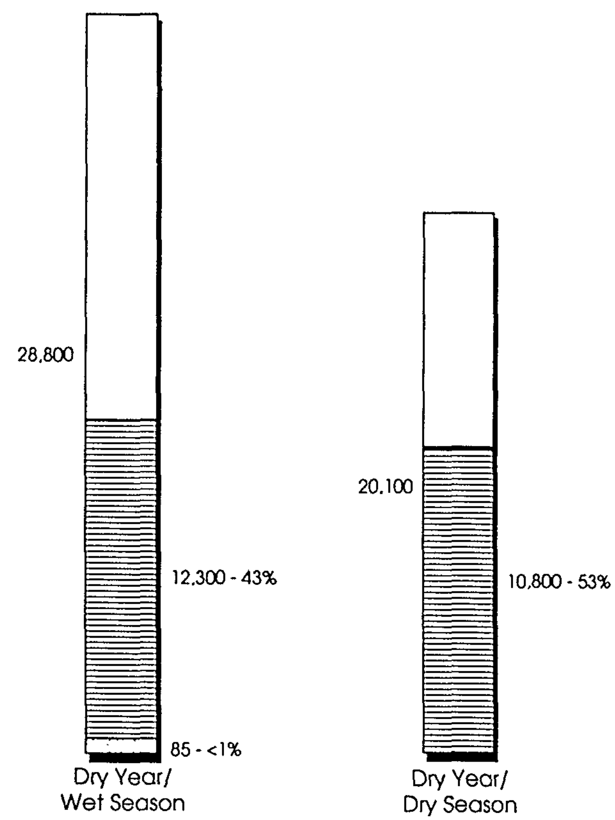

Explanation:

Pounds/day Sacramento River at Greene's Landing	
	Other Sources Percent of Sacramento River
	Sacramento Regional Wastewater Treatment Plant Percent of Sacramento River
	Sacramento Combined Sewer Overflow Percent of Sacramento River
	Sacramento Urban Runoff Percent of Sacramento River
	Sacramento Slough and Colusa Basin Drain Percent of Sacramento River

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Figure 5.
Relative Contribution of Ammonia from the Delta Tributaries

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Table 9. Range of Nitrate Plus Nitrite Concentrations[a]

Location	Concentration, mg/l
USEPA Drinking Water Standard Primary MCL	10 (as N) for nitrate 1 (as N) for nitrite
DHS Drinking Water Standard Primary MCL	45 (as NO_3) for nitrate
Banks Pumping Plant (1990-1993)	0.08-1.8
Sacramento River at Greene's Landing (1990-1993)	0.01-0.64
Sacramento Slough and Colusa Basin Drain (1990-1993)	<0.01-0.40
Sacramento Urban Runoff (1990-1993)	0.37-4.1
Sacramento Combined Sewer Overflow (1990-1993)	0.3-1.1
San Joaquin River at Vernalis (1990-1993)	0.10-2.70
Mud and Salt Sloughs (1986-1988)	<0.10-15

[a]Sacramento combined sewer overflow concentrations are for nitrate as N.

Table 10. Range of Total Phosphorous Concentrations

Location	Concentration, mg/l
Banks Pumping Plant (1990-1993)	0.09-0.26
Sacramento River at Freeport (1990-1993)	--
Sacramento Slough and Colusa Basin Drain (1990-1993)	0.13-0.37
Sacramento Urban Runoff (1990-1993)	0.1-0.66
Sacramento Combined Sewer Overflow (1990-1993)	0.2-1.9
San Joaquin River at Vernalis (1990-1993)	0.13-0.47
Mud and Salt Sloughs (1986-1988)	0.04-0.75

Data Analysis. The data analysis is based on the materials referenced above. (Note: some of the nutrient graphs and tabulated information is incomplete in this draft version. The revised draft will present all the information referenced above.)

How do nutrient concentrations compare between Banks Pumping Plant and the two Delta tributary benchmark locations?

The range of ammonia concentrations at Banks Pumping Plant (0.01 to 0.72 mg/l) is similar to the range at the Sacramento River at Greene's Landing (0.01 to 0.9 mg/l). Ammonia concentrations at the San Joaquin River at Vernalis are lower (0.01 to 0.28 mg/l). Nitrate concentrations at Banks Pumping Plant (0.08 to 1.8 mg/l) are intermediate between the Sacramento River at Greene's Landing (0.01 to 0.64 mg/l) and the San Joaquin River at Vernalis (0.10 to 2.70 mg/l). All source water nitrate concentrations at the benchmark locations are well below the MCL for finished water.

How do nutrient concentrations compare between discharges and their downstream tributary benchmark locations?

Ammonia concentrations in Sacramento urban runoff (0.3 to 0.78 mg/l) are within the range of concentrations in the Sacramento River at Greene's Landing. SRWTP concentrations (9.5 to 21 mg/l) are considerably higher. In the San Joaquin Basin, Mud and Salt slough concentrations range between 0.03 to 2.1 mg/l. All nitrate concentrations in discharges are well below the MCL for finished water. The ranges of concentrations are: <0.01 to 0.40 mg/l in Sacramento Slough and Colusa Basin Drain, 0.37 to 4.1 mg/l in Sacramento urban runoff, 0.3 to 1.1 mg/l in Sacramento combined sewer overflow, and <0.1 to 5 mg/l in Mud and Salt sloughs. Total phosphorus concentrations in the discharges range from 0.04 to 1.9 mg/l. Individually, the concentrations are: 0.13 to 0.37 mg/l in Sacramento Slough and Colusa Basin Drain, 0.1 to 0.66 mg/l in Sacramento urban runoff, 0.2 to 1.9 mg/l in Sacramento combined sewer overflow, and 0.04 to 0.75 mg/l in Mud and Salt sloughs.

What is the relative contribution of ammonia loads to the Delta?

The SRWTP is estimated to contribute about 50 percent of the ammonia load to the Sacramento River at Greene's Landing. This is likely the single most significant source in the Delta tributary watershed.

FINDINGS OF SIGNIFICANCE TO WATER UTILITIES

There were insufficient data to evaluate many of the contaminants of concern identified at the beginning of this study.

Based on data primarily from 1990 to 1993, the key findings for each contaminant evaluated are:

Organic carbon. The concentrations of organic carbon will not likely be reduced at any of the benchmark locations by control of the discharges examined. Based on early 1980s Fresno Nationwide Urban Runoff Program urban runoff DOC concentrations, it may be that Sacramento urban runoff is a significant contributor of organic carbon, but there are not recent local water quality data to confirm this possibility. If additional monitoring of Sacramento urban runoff confirms it as a significant source of organic carbon, control measures may be identified that would reduce the organic carbon concentrations at Greene's Landing.

Alkalinity. Alkalinity loads were not calculated. Based on the concentrations, the discharges would not likely have a significant effect on downstream alkalinity.

Bromide. The source of bromide is seawater that intrudes into the Delta, and the recirculation of bromide via the San Joaquin River. Control of the discharges identified in this study would not likely reduce bromide concentrations at the benchmark locations.

Controlling bromide will continue to depend on those water resource management operations which influence the amount of seawater intrusion in the western Delta.

Arsenic. Arsenic appears to be too ubiquitous to control in the Delta watershed. Arsenic concentrations at the benchmark locations will not be reduced by controlling any of the discharges examined. Additional monitoring of the Yuba and Bear Rivers watershed may indicate that controlling mine drainage would improve water quality at Greene's Landing. There are insufficient data at this time to characterize the impact of this drainage on the Sacramento River. It is uncertain, however, whether controlling mine drainage in the upper watershed would significantly affect arsenic concentrations downstream at Greene's Landing.

Total Dissolved Solids. Control of agricultural drainage in the San Joaquin Basin would result in lower concentrations in the San Joaquin River at Vernalis. Control of Sacramento Basin agricultural drainage may result in lower concentrations in the Sacramento River at Greene's Landing. However, due to Delta hydrology and the significant sources of TDS in Delta agricultural drainage and in seawater that intrudes into the Delta, it is unlikely that Sacramento Basin controls would significantly improve water quality at the Banks Pumping Plant. San Joaquin Basin controls would likely improve water quality at the Tracy Pumping Plant.

Nutrients. Of the three nutrients evaluated, it is likely that a reduction in ammonia concentrations at Greene's Landing could be achieved through control of the SRWTP effluent discharge. It is unlikely that significant reductions in the ammonia concentration at the Banks Pumping Plant would be achieved. However, controlling ammonia will not directly impact Delta source water quality. Ammonia is oxidized in-stream and does not survive to water treatment plant intakes. Nitrate and phosphorus concentrations would not be reduced at the benchmark locations by controlling the discharges evaluated in this study.

Key findings for each discharge evaluated are:

Sacramento Slough and Colusa Basin Drain. Alternative management of these agricultural drains may reduce concentrations of TDS in the Sacramento River at Greene's Landing, but would be less likely to have a significant impact on the concentrations at the Banks Pumping Plant due to the significant in-Delta sources of TDS. This discharge did not appear to be a significant source of other contaminants evaluated for this study.

Sacramento Urban Runoff. Additional monitoring may show this to be a significant controllable source of organic carbon. Based on early 1980s Fresno Nationwide Urban Runoff Program urban runoff DOC concentrations, it may be that Sacramento urban runoff is a significant contributor of organic carbon, but there are not recent local water quality data to confirm this possibility. Sacramento urban runoff did not appear to be a significant source of other contaminants evaluated for this study.

Sacramento Combined Sewer Overflow. This discharge did not appear to be a significant source of any of the contaminants evaluated for this study.

Sacramento Regional Wastewater Treatment Plant Effluent Discharge. This effluent discharge appears to be a significant source of ammonia in the Sacramento River, which, if controlled, could reduce ammonia concentrations in the Sacramento River at Greene's Landing. This discharge did not appear to be a significant source of other contaminants evaluated for this study. what!!

Mud and Salt Slough Drainage. These drains are significant contributors of total dissolved solids to the San Joaquin River. If controlled, total dissolved solid concentrations in the San Joaquin River at Vernalis would likely be reduced.

An overall finding of this study, in terms of any decisions to alternatively manage contaminant sources in the Delta tributary watershed (to improve Delta water quality as a source of drinking water) is that, in general the data do not adequately describe the sources of key drinking water contaminants. Even for those contaminants, where there were sufficient data to calculate loads, the results indicate that a significant proportion of the source remains unidentified.

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